

shingles applied over wood sheathing on rafters, an unheated attic, and a wood lath and plaster ceiling, based on a roof having a  $\frac{1}{2}$  pitch, for which the value of  $n$  is 1.2.

$$U_r = \frac{1}{\frac{1}{4.02} + \frac{1}{2.20} + \frac{1}{6.00} + \frac{0.781}{1.00}} = 0.605$$

$$U_{ce} = \frac{1}{\frac{1}{1.34} + \frac{1}{2.20} + \frac{1}{2.00}} = 0.588$$

Substituting these values in the preceding formula:

$$U = \frac{0.605 \times 0.588}{1.2 \times 0.605 + 0.588} = 0.271$$

B.t.u. per hour, *per square foot of roof area* per 1 deg. fahr. difference in temperature between the air near the underside of the ceiling and the outside air.

Combined coefficients for many common types of pitched roofs and top-floor ceilings for unheated attics are given in Table 32.

If the unheated attic space between the roof and ceiling has no dormers, windows or vertical wall surfaces, the combined coefficients given in Table 32 may be used for determining the heat loss through the roof construction between the attic and top-floor ceiling, but it should be noted that the coefficients given in Table 32 should be multiplied by the roof area and not by the ceiling area. If the unheated attic contains windows, ventilators or vertical wall surfaces, which would tend to reduce the temperature in the attic to a temperature approaching or equaling the outside temperature, the roof should be neglected and only the top-floor ceiling construction and the corresponding ceiling area taken into consideration, using the coefficients given in Tables 26 or 27. The attic temperature should then be taken the same as the outside temperature. In this case the reasoning regarding the loss of heat from a surface by radiation, referred to in the preceding discussion regarding the determination of the combined coefficients of a ceiling, unheated attic and roof, does not apply to the heat loss from the attic floor or top-floor ceiling, on account of the fact that the undersurface of the roof will have about the same temperature as the attic floor. As stated before, if the attic is heated, the top-floor ceiling should be neglected, and only the roof structure, with whatever ceiling is applied to the underside of the roof rafters, taken into consideration in determining the heat losses through the roof.

The temperature in an attic space containing no dormers, windows, vertical wall spaces or ventilators may be estimated by means of the following formula:

$$t_b = \frac{t U_{ce} + n t_o U_r}{U_{ce} + n U_r} \quad (11)$$

where

$t$  = inside temperature near ceiling.

$t_b$  = temperature in attic.

$t_o$  = outside temperature.

If in the foregoing problem, involving the determination of the combined coefficient of transmission, the inside temperature  $t$  is 70 deg. fahr. and the outside temperature is  $-10$  deg. fahr., the attic temperature, based on equation (11) will be:

$$t_b = \frac{70 \times 0.588 + 1.2 \times (-10) \times 0.605}{0.588 + 1.2 \times 0.605} = 26 \text{ deg. fahr.}$$

As previously stated, if the attic contains windows, ventilators, etc., the attic temperature will approach or equal the outside temperature, the roof will provide little or no resistance to the passage of heat, and the heat loss through the upper part of the building may be estimated by assuming the attic temperature to be the same as the outside temperature and using the heat transmission coefficient of the ceiling.

The heat loss through floors into basements and into unheated rooms kept closed may be computed by assuming a temperature for these rooms of 32 deg. fahr.

### AREAS WHERE TRANSMISSION LOSSES OCCUR

Heat is lost from a building by transmission through all of those surfaces which separate heated spaces from the outside air or from unheated colder spaces within the building. In general, five kinds of surfaces are involved: (1) outside walls; (2) outside glass; (3) inside walls or partitions next to unheated spaces; (4) ceilings of upper floors, either below a cold attic space or as the underside of a roof slab, and (5) floors of heated rooms above an unheated space. In most cases, only items (1) and (2), outside wall and glass surface, are considered. Failure to take account of the other heat-losing surfaces, items (3), (4) and (5), when they exist in a building, has generally resulted in more or less dissatisfaction with the operation of the heating plant, as a result of failure to heat the rooms having such surfaces as indicated by items (3), (4) and (5).

The net outside wall surface is usually determined by reference to the scale plans and elevations of the building concerned. In some cases, of course, the actual building may have to be measured. The total area of all outside openings which are occupied by windows and doors is accurately measured and listed as *glass*. The *glass* area is then deducted from the total outside wall area for each room and the difference is the net wall area. The outside wall areas for any floor should be based on the vertical floor-to-floor heights and the horizontal distance from center to center of partitions separating different rooms. If there are no partitions, measure from inside face of one wall to inside face of next wall. The areas of walls, ceilings and floors next to cold or unheated spaces are found, of course, by taking the inside dimensions of such areas, measured on the heated side.

### CALCULATIONS FOR TRANSMISSION LOSSES

The calculations for heat transmission losses are made by multiplying the area  $A$  in square feet of wall, glass, roof or floor through which the loss takes place, by the proper coefficient  $U$  for such construction (Tables 9 to 33, or by computation as described under Transmission Coefficients